# REAL TIME THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN TRICUSPID VALVE DISEASES

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***"learn to heal"***

# CERTIFICATE

This is to certify that the dissertation entitled **"REAL TIME THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN TRICUSPID VALVE DISEASES"** is the bonafide original work of **DR.J.JACOB JUSTIN** in partial fulfillment of the requirements for D.M. Branch-II (CARDIOLOGY) examination of THE TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY to be held in August 2009.The period of post-graduate study and training was from August 2006 to July 2009.

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# DECLARATION

I **Dr.J.JACOB JUSTIN,** solemnly declare that this dissertation entitled, **"REAL TIME THREE-DIMENSIONAL ECHOCARDIOGRAPHY IN TRICUSPID VALVE DISEASES"** is a bonafide work done by me at the department of Cardiology, Madras Medical College and Government General Hospital during the period 2006 – 2009 under the guidance and supervision of the Professor and Head of the department of Cardiology of Madras Medical College and Government General Hospital, Professor **R. SUBRAMANIAN .MD.DM .** This dissertation is submitted to The Tamil Nadu Dr.M.G.R Medical University, towards partial fulfillment of requirement for the award of **D.M. Degree (Branch-II) in Cardiology.**

Place : Chennai

Date: **Dr.J.JACOBJUSTIN**

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# CONTENTS

# INTRODUCTION

The tricuspid valve is a forgotten valve It has multi-component complex structure . The tricuspid valve is composed of three leaflets (anterior, posterior and septal) attached to a fibrous annulus.The three-dimensional shape of the tricuspid annulus is complex and does not conform to a flat ring .Tricuspid regurgitation is the most common pathology affecting the tricuspid valve. An understanding of the pathological process underlying tricuspid regurgitation is necessary to determine the optimal management strategy. Usually tricuspid regurgitation is secondary to left-sided valvular pathology (mostly mitral valve disease) with pulmonary hypertension and right ventricular dilatation. Because the tricuspid annulus is a component of the right ventricle it will dilate also. Unfortunatelytricuspid valve evaluation continues to be a major problem in the surgical decision making process.

Unlike the aortic and mitral valve it is not possible to visualize all tricuspid valve cusps simultaneously in one cross-sectional view by standard transthoracic two- dimensional echocardiography During transesophageal 2D Echo small changes in transducer angle, probe position and rotation may bring to light some additional tricuspid valve details .However, because of the position of the tricuspid valve in the far field in relation to probe, transesophageal 2DEcho can still only provide limited information and can also not visualize all tricuspid cusps simultaneously. At the time of surgery the decision to repair the tricuspid valve may be changed due to discrepant tricuspid annular diameter findings between pre-operative two-dimensional transthoracic or transesophageal echocardiography and direct surgical visualization . These unsatisfactory results call for a reappraisal of surgical techniques for TR that in the past might have been based on an incomplete knowledge of tricuspid annulus geometry.

Tricuspid vavle is affected by a variety of congenital and acquired diseases Rheumatic heart disease causes tricuspid valve stenosis in up to 8% of patients. Unfortunately, tricuspid valve stenosis is easily missed at clinical examina tion except in advanced cases when a high degree of clinical suspicion exists. Undetected and thus uncorrected tricuspid valve stenosis may lead to postoperative low cardiac output despite successful relief of left-sided valve disease and carries a high mortality and morbidity.

Two-dimensional echocardiography (2DE) can detect thickened tricuspid valve leaflets and a reduced tricuspid valve orifice diameter, and continuous-wave Doppler allows estimation of the tricuspid transvalvular pressure gradient. However, in most patients, it is not possible to visualise all three tricuspid valve leaflets simultaneously with 2DE and measure the tricuspid valve area .

Transthoracic real-time three-dimensional echocardiography (RT3DE) may be a valuable imaging modality for the examination of stenotic tricuspid

valves because all leaflets can be seen simultaneously and studied from both atrial and ventricular aspects. Ebsteins anomaly is characterized by by tethering of the tricuspid valve to the septum resulting in displacement of the septal and posterior leaflets. 2D echo is of limited value in making the diagnosis of this entity. It does not visualize the posterior leaflet involved in tethering .

Also it does not provide a comprehensive assessment of the tethered and non tethered areas of tricuspid leaflets when repair is considered Obviously, 2D TTE is limited in visualizing the complete tricuspid anatomy . Since real-time 3D echocardiography (RT3DE), has become available for clinical practice, it is now possible to examine the tricupid valve more completely. In three-dimensional (3D) echocardiography studies this goal could be achieved but at the cost of an increase in procedural duration . Real-time three-dimensional echocardiography (RT3DE) can visualize the tricuspid valve from both the ventricular and atrial side in detail .The real-time, 3- dimensional echocardiography (RT3DE) can be used to provide fast and noninvasive estimates with high image resolution that is more accurate and physiologically realistic than those measured by conventional imaging techniques

# AIM OF THE STUDY

The study aims at utilizing Real time three-dimensional transthoracic echocardiography (RT3DE) technique for

a. qualitative and quantitative analysis of tricuspid valve in both normal and dieased states

b. comprehensive assessment of individual leaflets of tricuspid valve commisures ,leaflets ,valve area and annulus in normal individuals

c. detailed analysis of tricuspid annulus, commisures, valve area and leaflets in patients with functional regurgitation.

d. assessment with descriptive tricuspid valve morphology for each tricuspid valve leaflets and each tricuspid valve commissure and tricuspid valve area in patients with rheumatic tricuspid valve stenosis

e. comprehensive assessment of individual leaflets of tricuspid valve and annulus in patients with organic tricuspid valve diseases like ebsteins anomaly and infective endocarditis

The study aims to compare the findings between 2D TTE and RT3D echo.

# REVIEW OF LITERATURE

## ANATOMY

### Leaflets

The tricuspid valve has three distinct leaflets described as  septal, anterior, and posterior. The tricuspid orifice is placed in the medial and anterior part of the floor of the right atrium and with the heart in its natural position, the orifice is almost vertical. . Of the valve cusps the anterior  is usually the largest and extends from close to the infundibulum to nearly the lateral margin of the orifice .The posterior leaflet is smaller and appears to be of lesser functional significance. The septal leaflet is in immediate proximity of the membranous ventricular septum, and its extension provides a basis for spontaneous closure of the perimembranous ventricular septal defect.

### Papillary Muscles & Chordae

There are three sets of small papillary muscles, each set being composed of up to three muscles. Of the main papillary muscles the large anterior muscle is inserted into the adjacent margins of the anterior and posterior cusps, the smaller posterior into the posterior and septal cusps, and the small septal muscle into the septal and anterior cusps. The chorde tendine and papillary muscles are thus attached almost in a ring around the tricuspid valve orifice and tether the edge of the valve to three different points of the compass. The chordae tendinae arising from each set are inserted into two adjacent leaflets. The anterior set chordae insert into half of the septal and half of the anterior leaflets. The medial and posterior sets are similarly related to adjacent valve leaflets

**Tricuspid annulus**

The tricuspid valve is the most apically placed valve with the largest orifice among the four valves. The tricuspid annulus is oval-shaped and when dilated becomes more circular. It is 20% larger than mitral valve annulus . Normal Tricuspid valve annulus diameter is 3.0 to 3.5 cm The cavity of the right ventricle has a roughly three-sided pyramidal shape with the tricuspid orifice set in the right posterior wall. In the roof of the ventricle a thick muscular ridge, the crista supraventricularis separates the tricuspid orifice from the infundibulum and thus helps to divide the ventricular cavity into a posterior inflow tract and an anterior outflow tract.51 The tricuspid orifice projects into the cavity of the right ventricle rather like a funnel and is set an angle of roughly 60° to the outflow tract The function of the valve may be studied in the dead heart by distending the ventricular cavity with water (Brunton, 1906). Viewed from the right atrium, valve closure is seen to be effected by apposition of the atrial surfaces of the cusps almost at their margins The cusps bulge upwards like sails but are prevented from inversion by the chordae which thus ensure competence of the valve.1

**Tricuspid valve by 3D echo**

**Tricuspid valve in systole and diastole by 3D echo**

The mitral valve, in contrast to the tricuspid, does not project forwards into the ventricular cavity but is set more or less flush with the wall. In other words the inflow and outflow tracts of the left ventricle are parallel to each other, whereas on the right they are at an angle of about 60 degrees .

Therefore, by moving laterally in systole, the anterior cusp of the mitral valve can help to obliterate its inflow tract whilst no such action is possible with the tricuspid valve. In addition, according to Walmsley (1929), the two large mitral papillary muscles actually obliterate part of the inflow tract in systole: there is no comparable muscular action in the right ventricle.21 It is therefore apparent that the tricuspid valve is anatomically much weaker than the mitral as regards the prevention of incompetence. The tricuspid valve may malfunction due to structural malformation or secondary to other cardiac pathology

**ETIOLOGY**

The most common presentation of Functional Tricuspid valve disease is of tricuspid regurgitation due to

- Right ventricular hypertension due to pulmonary hypertension either primary or secondary to left sided diseases

As pulmonary hypertension develops leading to right ventricular dilatation, the tricuspid valve annulus will dilate. The circumference of the

annulus lengthens primarily along the attachments of the anterior and posterior leaflets. The septal leaflet is fixed between the fiberous trigones, preventing lengthening. As the annular and ventricular dilation progresses, the chordal papillary muscle complex becomes functionally shortened. This combination prevents leaflet apposition, resulting in valvular incompetence.

Eisenmenger's syndrome and primary pulmonary hypertension lead to the same pathophysiology of progressive right ventricular dilation, tricuspid annular enlargement, and valvular incompetence.

Etiology of Primary Tricuspid Valve Disease

- Congenital
    - -Ebstein’s anomaly
    - -Congenital tricuspid stenosis
    - -Tricuspid atresia
- Rheumatic valve disease, generally in association with rheumatic mitral valve disease
- Infective endocarditis
- Carcinoid heart disease
- Toxic (eg, Phen-Fen valvulopathy or methysergide valvulopathy)
- Tumors (eg, myxoma)
- 
- Iatrogenic—pacemaker lead trauma
- Trauma—blunt or penetrating injuries

- right ventricular infarction.
- Marfan syndrome can lead to prolapsing leaflets, elongation of chordae, or chordal rupture producing valvular incompetence.

**CLINICAL PRESENTATION**

Tricuspid insufficiency has been recognized clinically since 1836 when Benson described the jugular venous wave abnormalities in a case proven at autopsy. In the following year King stated that "on occasion of most copious influx (the right ventricle) becomes dilated: upon which the curtains of the tricuspid valve are drawn aside, an aperture of reflux is produced, and the force of the ventricle is diverted from the pulmonary circulation." The clinical observation that patients with pulmonary hypertension had less orthopnea and paroxysmal nocturnal dyspnea once they developed tricuspid insufficiency would seem to support King's concept. This is consistent with the hypothesis that rising pulmonary arteriolar resistance by producing pulmonary hypertension, right atrioventricular distention, and tricuspid insufficiency, diminishes forward flow and progressive overloading of the left atrium and pulmonary capillary bed. Patients with tricuspid regurgitation have the presenting symptoms of fatigue and weakness related to a reduction in cardiac output.

Right heart failure leads to ascites, congestive hepatosplenomegaly, pulsatile liver, pleural effusions, and peripheral edema. In the late stages these patients are wasted with cachexia, cyanosis, and jaundice.

In 1908 MacKenzie, using jugular phlebograms, presented what he considered to be stages of severity of tricuspid regurgitation It is generally agreed that the initial change in right atrial curves is a decrease in the depth of the X descent which eventually almost disappears as the V wave becomes larger, leading to "ventricularization" of the curve with severe tricuspid insufficiency . Impressive jugular venous distention with an *s* wave or fused *c* and *v* waves, followed by a prominent *y* descent, is present. During inspiration this finding is accentuated because of the physiologic increase in venous return

Duroziez is credited with the description of the physical findings of tricuspid insufficiency. Included were a xiphoid systolic murmur, enlarged right atrium, distended neck veins with systolic pulsation, hepatic enlargement and pulsation, and peripheral cyanosis. Atrial fibrillation is common. The cardiac exam is notable for an $S_3$ that increases with inspiration and decreases with a Valsalva maneuver, increased $P_2$ if pulmonary hypertension has developed, and a parasternal pansystolic murmur increasing with inspiration. The characteristic murmur with its inspiratory accentuation may be missed

easily in the presence of other systolic murmurs or in mild tricuspid insufficiency.The hepatic pulsation is readily detected only with severe tricuspid insufficiency . Furthermore, the presence and severity of tricuspid insufficiency are remarkably labile, being greatly influenced by exercise, deep breathing, emotions, and the degree of cardiac compensation .

**PATHOPHYSIOLOGY**

The tricuspid annulus dilatation and leaflet tethering were important mechanisms in the development of functional TR. Annulus dilatation compromised leaflet closure or coaptation by limiting the amount of leaflet overlap. Changes in RV geometry presumably caused displacement of the papillary muscles, resulting in tethering of the Tricuspid leaflets.

The chest x-ray demonstrates cardiomegaly, increased right atrial and ventricular size, a prominent azygous vein, pleural effusion, and upward diaphragmatic displacement due to ascites. Echocardiography best assesses the degree of regurgitation, structural abnormalities of the valve, pulmonary artery pressures, and right ventricular function both preoperatively and intraoperatively. A shift in the atrial septum to the left and paradoxical septal motion are consistent with right ventricular systolic overload. Pulsed Doppler and color flow help identify systolic right ventricular to right atrial flow with inferior vena cava and hepatic vein flow reversal. Contrast echocardiography can be useful with a rapid saline bolus injection producing microcavities that are visible on echo, demonstrating to-and-fro motion across the valve orifice and reversal into the inferior vena cava and hepatic veins.

Angiocardiography has been unreliable in demonstrating tricuspid insufficiency.27 Thehigh-pressure delivery of contrast material into the right ventricle may cause the catheterto regurgitate into the right atrium or stimulate premature ventricular contractions which produce insufficiency. Only if adequate opacification is achieved and no regurgitation is seen can one state confidently that tricuspid insufficiency is absent. Cardiac catheterization will document increased right atrial and right ventricular end-diastolic pressure. The right atrialpressure tracing has an absent X descent, prominent V wave, and "ventricularization" of the right atrial tracing, and the degree of pulmonary artery hypertension is documented. Pulmonary artery pressures of over 60 mm Hg are usually due to left-sided lesions leading to secondary tricuspid regurgitation. A right ventriculogram has been used but is unnecessary with current echocardiographic evaluation.

It is well known that after mitral valve surgery patients may clinically deteriorate due to underestimated tricuspid pathology and significant residual or developing TR . Tricuspid regurgitation in patients with mitral valve disease is associated with poor outcome and predicts poor survival, heart failure, and reduced functional capacity2. It might appear many years after surgery

and might not resolve after correcting the mitral valve lesion. Late TR might be caused by, left heart disease, right ventricular dysfunction and dilation, persistent pulmonary hypertension, chronic atrial fibrillation, or by organic(mainly rheumatic) tricuspid valve disease. Most commonly, late TR is functional and isolated, secondary to tricuspid annular dilation. Outcome of isolated tricuspid valve surgery is poor, because RV dysfunction has already occurred at that point in many patients. Mitral valve surgery or balloon valvotomy should be performed before RV dysfunction, severe TR, or advanced heart failure has occurred.

Tricuspid annuloplasty with a ring should be performed at the initial mitral valve surgery, and the tricuspid annulus diameter >3.5 cm is the best criterion for performing the annuloplasty4

The ideal tricuspid valve annuloplasty would resolve the deficiency in tricuspid valve coaptation caused by both tricuspid annular dilatation and leaflet tethering. However, the concept of current TV annuloplasty is to stabilize the area of the tricuspid annulus that is primarily responsible for annular dilatation. Therefore, annuloplasty performed to reduce the tricuspid annulus might not be sufficient to correct the tethering of tricuspid vave . Tricuspid valve tethering was identified as an independent predictor of residual TR early after TV annuloplasty28. A similar finding of echocardiographic

predictors has been described for mitral valve annuloplasty in patients with functional mitral regurgitation.

Calafiore et al showed that mitral valve coaptation height was a preoperative predictor for the failure of mitral annuloplasty in patients with functional mitral regurgitation3. In contrast, the degree of tricuspid annulus dilatation was also a preoperative risk factor for postoperative negative results. 3In, a future tricuspid valve surgery addressing both leaflet tethering and annular dilation should be developed to overcome the limitations of annular reduction alone in functional TR. Furthermore, assessment of preoperative tricuspid valve tethering might be essential to define the surgical indication for tricuspid valve replacement in patients with severe functional TR .Most surgeons consider the use of an annuloplasty ring an essential part of basic repair techniques for obtaining good results. However, the rings currently being used for tricuspid annuloplasty were originally released for the mitral valve, and moreover, most rings are formed in a single plane with variation, whereas the actual tricuspid annulus may have a nonplanar, or 3D, structure5,6.

Although 2D TTE is helpful to assess tricuspid valve function and to detect TR severity it has important limitations in describing tricuspid valve morphological details, such as tricuspid annular diameter and annular area. The impact of echocardiographic-guided treatment on outcome after tricuspid valve surgery is not well defined. A limitation of the 2D echocardiography was the

inability to adequately characterize the posterior leaflet from apical 4-chamber view.

In a study in Int J Cardiovasc Imaging (2007) “Assessment of normal tricuspid valve anatomy in adults by real-time three-dimensional echocardiography” by Ashraf M. Anwar et al 41 reports that it was possible to analyse tricupid valve anatomy by RT3DE and a detailed anatomical structure including unique description and measurement of tricuspid annulus shape and size, tricuspid leaflets shape, and mobility, and tricuspid commissural width in majority of patients. Moreover, RV size and geometry are technically difficult to determine accurately with 2D echocardiography because of its anatomic complexity can be measured with 3D echo. Changes of ventricular geometry may cause the tethering of tricuspid leaflet through the displacement of the papillary muscles, determining the outcome of tricuspid annuloplasty.

Three-dimensional imaging techniques may have the potential to provide more accurate information for tricuspid valve deformation ,RV function and geometry, RT3DE combined with software is useful for assessing the unique 3D geometry of the tricuspid annulus in healthy subjects and in patients with functional TR. In a study by Michael Y. Henein, Christine A. O'Sullivan, Wei Li, Mary Sheppard, Yen Ho, John Pepper, Derek G. Gibson Departments of Echocardiography, Cardiac Morphology, Cardiac Pathology and Cardiac Surgery, Royal Brompton Hospital, London, UK “Evidence for rheumatic

valve disease in patients with severe tricuspid regurgitation long after mitral valve surgery” **(**The Journal of Heart Valve Disease 2003*)*30 states that severe tricuspid regurgitation is a well-recognized, long-term complication of rheumatic mitral valve replacement that impairs the functional results of surgery, its exact basis remains unclear and its management is unsatisfactory. A detailed assessment of tricuspid valve morphology and function using 2D transthoraxic echocardiography with 3D reconstruction, and knowledge of the structural basis of this condition may thus improve its long-term management, possibly with early tricuspid valve repair.

In patients with predominant tricuspid regurgitation, the negative consequences of right ventricular volume overload develop slowly. Acute tricuspid regurgitation due to traumatic rupture or complete excision of the tricuspid valve as the treatment for infective endocarditis can be well tolerated for years if the pulmonary artery pressure is not elevated45

**TRICUSPID STENOSIS;**

It has become almost traditional to state that tricuspid stenosis is rare and that the diagnosis is difficult . Mackenzie (1908) wrote that he had heard a tricuspid murmur only three times in his life46. The stress that has been laid on the rarity and difficulty of diagnosis of the affection combined with statements such as those above, have tended to make the average practitioner forget that the tricuspid valve is not infrequently affected. . Tricuspid stenosis is most

commonly rheumatic. It is extremely rare to have isolated tricuspid stenosis, as some degree of tricuspid regurgitation will be present. Mitral valve disease coexists with occasional involvement of the aortic valve. The third world and especially the Indian subcontinent still have a significant prevalence of rheumatic tricuspid valvular disease

**INCIDENCE**

There exists a good deal of discrepancy between several of the analyses that have been published, doubtless dependent largely on the degree of stenosis. Coombs (1924) gives the following figures of the incidence of valve injury in 97 cases of rheumatic heart disease, including the lesser as well as the greater degrees of involvement.

These were combined in the following ways:

Mitral alone .. .. .. .. .. .. .. 27 cases

Mitral and aortic .. .. .. .. .. 35

Mitral and tricuspid .. .. .. .. .. 12

Mitral, aortic, and tricuspid .. .. .. .. .. 21

Mitral, aortic, tricuspid, and pulmonary .. .. .. 2

The incidence at Bristol of clinical tricuspid stenosis in rheumatic heart disease was 14 per cent. Cabot (1926) gives the incidence at 15 per cent while Dressler

and Fischer put the incidence at 24 per cent. Bland, Jones, and White (1935) analyzed the pathological findings in 100 cases of fatal rheumatic disease below the age of 21 in whom the diagnosis of tricuspid valve disease had not been made during life. Out of 100 cases, the mitral valve was affected in 98 instances, the aortic in 71, the tricuspid in 30, and the pulmonary valve in 5,

**PATHOLOGY**

According to the pathologist, the tricuspid valve becomes stenosed when the ostium is reduced to between 6 and 8 cmsq., the normal being between 12 and 14 cm sq. (Cabot, 1926)17.

The valve becomes incompetent for three reasons: (1) extensive scarring in which regurgitation accompanies stenosis; (2) slight shortening of the chorda tendinee or fibrosis of the valve edge resulting in regurgitation, without necessarily causing stenosis; The anatomic features of stenosis are similar to mitral stenosis with fusion and shortening of the chordae commissural fusion and leaflet thickening. Fusion along the free edges and calcific deposits on the valve are found late in the disease. The preponderance of cases are in young women.

**CLINICAL DIAGNOSIS**

Duroziez (1868) reported 10 cases of tricuspid stenosis with ages varying from 22 to 64, and asserted that tricuspid disease was more common

than was usually accepted. He was impressed by the fact that many could lie flat in bed in spite of gross cardiac deficiencies: He drew attention to the diastolic murmur at the lower end of the sternum that pointed to the diagnosis, and wrote: " The disease should be diagnosed when the patient is a female, has a history of rheumatism, and of dvspnea, palpitation, edema, often with remissions and exacerbations, is cyanosed, has mitral stenosis with an enlarged right heart, particularly if the atrial enlargement can be made out . If in addition to this the patient has a separate murmur best heard over the ensiform or the fifth or sixth right costal cartilage, then the diagnosis becomes reasonably certain. There is no one infallible diagnostic sign but there are numerous signs, any one of which should initiate a search for other clues. The diagnosis may be suspected from the history alone as Levine and Thompson (1937) have pointed out.

Any adult patient who has repeated attacks of edema and ascites and yet is able to lead a sedentary life with the aid of diuretics and carry on with symptoms that ordinarily would cause the early demise of the patient, probably has tricuspid stenosis. Several observers, have commented on the peculiar colour, a mixture of jaundice and cyanosis, that is presented by these patients, pointing out that this should always suggest the possible diagnosis of tricuspid stenosis. Much reliance cannot, however, be placed on this sign in as much as its commonest pathogenesis lies in the inability of an engorged or diseased liver to excrete rapidly enough the blood pigment from a pulmonary infarct .A

patient with a rheumatic heart and ascites who is able to sleep without extra pillows probably has tricuspid stenosis. This is due to the lack of pulmonary vascular engorgement, as confirmed by X-ray study, resulting from the obstruction to the free flow of blood through the right heart.

Clinical features are consistent with reduced cardiac output producing the symptoms of fatigue and malaise. Significant liver engorgement produces right upper quadrant tenderness with a palpable liver with a presystolic pulse. Ascites produces increased abdominal girth. Significant peripheral edema or anasarca can develop. Severe tricuspid stenosis may mask or reduce the pulmonary congestion of mitral stenosis due to reduced blood flow to the left side of the heart. The low output state of the patient is prominent Pulsation in the neck veins has for over one hundred years excited comment, whether the jugular polygram is diagnostic. The elevated venous blood pressures between 19 and 27 cm. of water noted in the absence of (edema, constrictive pericarditis, and mediastinal obstruction should be taken as a strong diagnostic point in favour of tricuspid stenosis.

If the patient remains in normal sinus rhythm, the right atrial tracing and jugular venous pulse have prominent *a* waves that accentuate with inspiration.

Tschilikin (1930) stated that the only pathognomonic sign of tricuspid stenosis is a localized diastolic murmur at the lower end or to the right of the sternum. However, this sign is often, probably usually, absent, The cardiac

murmur is mid-diastolic, increases with inspiration, is heard maximally along the left sternal border, and may have an opening snap.

Atrial fibrillation occur just as frequently in cases of pure mitral valve disease, especially the so-called " tight type," as in tricuspid stenosis. The circulation times were all markedly prolonged, the right heart times averaging 20 seconds (ether method) against a normal average of 6 seconds. As the right atrial pressure increases, venous congestion leads to distention of the jugular veins, ascites, pleural effusion, and peripheral edema. The right atrial wall thickens and the atrial chamber dilates.

The chest x-ray demonstrates cardiomegaly with an increase in the right atria and pulmonary artery size. Dressler and Fischer emphasized as an important diagnostic pointer the presence of marked enlargement of the heart to the right by X-ray especially when associated. with absence of pulmonary congestion at the hilus of the lung.. Lian and Marchel (1936) drew attention to the deviation of the esophagus to the left in the presence of marked enlargement of the heart to the right.The ECG will demonstrate increased P-wave amplitude if the patient is in normal sinus rhythm.

Echocardiography reveals the diagnostic features of diastolic doming of the thickened tricuspid valve leaflets, reduced leaflet mobility, and a reduced orifice of flow. The Doppler flow pattern across the tricuspid valve has a prolonged slope of antegrade flow. The diastolic gradient between the right

atrium and right ventricle is significantly elevated at 2 to 5 mm Hg mean pressure17 .The patient's ability to tolerate stenotic lesions of the tricuspid valve is dictated to a large degree by the natural history of the mitral or aortic valve disease.

Although the tricuspid valve leaflets can sometimes be visualised simultaneously by 2DE from an angulated view, measurement of Tricuspid valve area is only rarely possible because even when all leaflets are visualised,simultaneously the image cross section will not be at the correct tricuspid valve area level. Unfortunately, from all other 2DE views, including the atypical parasternal projection, only two tricuspid valve leaflets can be visualised simultaneously. Estimation of the transtricuspid pressure gradient is usually only performed when a morphologically abnormal tricuspid valve is seen. Therefore, good morphological imaging and description of the tricuspid valve are essential in identifying tricuspid valve.

With RT3DE, each separate tricuspid valve leaflet can be assessed with regard to thickness, mobility, calcification and its relationship to other tricuspid valve leaflets.29 In addition, RT3DE provides unique tricuspid valve measurements such as Tricuspid valve area $_{3D}$ and commissural width at the time of maximal tricuspid valve opening.

In a study by Ashraf M Anwar et tal in Heart 2007 Evaluation of rheumatic tricuspid valve stenosis by real-time three-dimensional

echocardiography40 states that tricuspid valve area by 3D echo had better discriminative value than tricuspid gradient for the separation of patients with rheumatic heart disease with tricuspid valve involvement from those with rheumatic heart disease without tricuspid valve involvement or from normal controls, tricuspid valve area 3D correlated with the mean transtricuspid pressure gradient

**Ebstein's anomaly of the tricuspid valve**

Ebstein anomaly is characterized by heterogenous and variable tethering of the Tricuspid valve to the underlying right ventricle and ventricular septum .with the septal and the posterior leaflets more commonly involved in tethering and dysplasia of the leaflets. The variable degrees of redundancy and dysplasia determine the displacement of the functional tricuspid opening toward the trabecular portion and outflow tract of the right ventricle . The histopathology of the right ventricular wall reveals a decrease or total absence of myocardial fibers in the inlet portion . The apical trabecular portion of the right ventricular free wall shows a characteristic pattern of anomalous muscular bands that connect the ventricular septum to the free wall . Moreover, in the infundibular portion of the ventricular outflow tract, myocardial fibers are diminished in number, making it very thin. Subpulmonary and pulmonary obstructions can also be present In addition, 25% of patients with Ebstein's anomaly also present with a Wolf-Parkinson-White pre-excitation syndrome

The hemodynamic effects are related to the tricuspid regurgitation, the existence of an atrial septal defect and the degree of dysfunction of the atrialized portion of the right ventricle. Some cases have tricuspid stenosis owing to reduction of the functional valve opening secondary to fusion of the leaflets. Echocardiography is the non-invasive method of choice in the diagnosis of this condition, as it makes it possible to evaluate the degree of leaflet tethering, the characteristics of the leaflets and the subvalvular apparatus, the degree of regurgitation or tricuspid stenosis, the morphological and functional alterations in the atrialized right ventricle and associated anomalies, all of which aid in planning the type of surgery to perform .54

Tethering of the septal leaflet results in apparent displacement of of its orgin toward the apex of RV which is easily diagnosed on 2D echo For definition, the distance between mitral or tricuspid annulus plane and the insertion of tricuspid pathologic leaflet is greater than 1 cm (or more than 0.8 mm/m²). Frequently a tethering of posterior tricuspid leaflet to RV wall is present. These modifications lead to atrialization of a RV The atrialized RV/total RV ratio more than 30% indicates severe disease with poor prognosis. Commonly the tricuspid regurgitation is severe with low velocity on continuous wave Doppler .However the 2D echo is of limited value in not delineating the morphology of the valves it also doesn't visualize the posterior

leaflet involved in tethering .it does not provide comprehensive assessment of the tethered and non tethered areas of tricuspid leaflets which have an implication in the management of tricuspid valve repair. 3D echo visualizes the posterior leaflet involved in tethering .and provide comprehensive assessment of the tethered and non tethered areas of tricuspid leaflets . In addition 3D echo demonstrates characteristic bubble like appearance produced by bulging of the non tethered areas of tricuspid leaflets.

In a study "live real time three-dimensional transthoracic echocardiographic assessment of ebstein's anomaly by Vinod patel, Navin c nanda. echocardiography, volume 22, november 2005" 56 states that the technique was found useful in assessing the distribution and extent of tethering of each of the three leaflets of the tricuspid valve to the underlying right ventricular walls and the ventricular septum. The characteristic bubble-like appearance resulting from bulging of the non-tethered areas of the tricuspid leaflets was also well visualized in three dimensions and their size measured. Thus, an estimate of the nontethered or free segments of all three leaflets of the tricuspid valve could be obtained using this technique. This has important implications when considering these patients for surgical repair of the tricuspid valve . Visualization of all three leaflets of the tricuspid valve and their extent of tethering by 3D TTE also made it easier to identify the boundaries of the functioning right ventricular chamber potentially providing a more reliable assessment of its volumes and ejection fraction.

Endocarditic lesions and vegetations are clearly visible by echo; the valve may be destroyed and septic pulmonary emboli are a common feature. The tricuspid valve in carcinoid syndrome is thickened with retracted leaflets fixed in a semi open postion throughout the cardiac cycle.

**Echocardiographic assessment of "tricuspid valve"**

Tricuspid valvular apparatus can be evaluated by transthoracic and transesophageal echocardiography10., The three-dimensional echocardiography will offer the integral image of tricuspid valve .The TV can be well visualized from multiple transthoracic echocardiographic (TTE) views

Parasternal short-axis view; septal and posterior leaflets are seen

Apical four chambers view;

Subcostal view.

Right ventricular inflow tract view, - In the these three views the septal and anterior leaflets can be visualized.

Transesophageal echocardiography (TEE) offers multiple views for the tricuspid valve evaluation planes23.24

- 4C view, similar to TTE 4C view;

- At the base of the heart in a 60° view.

In these two views the anterior and septal leaflets can be visualized:

- Bi-caval view;

- Gastric longitudinal view of RV.)

The last two allow the visualization of the anterior and posterior leaflets

The tricuspid inflow and tricuspid regurgitation can be evaluated from multiple ecocardiographic windows by spectral and color Doppler31. The effective orifice area of the tricuspid valve is greater than that of the mitral valve and the right cavities pressure is smaller than on the left. Because of that the inflow velocities are lower for TV than for the mitral valve. Normally, the tricuspid diastolic flow E/A ratio exceeds 1.0.1 Color flow imaging can be used to detect the presence of tricuspid regurgitation (TR). This is present physiologically in 80-90% of healthy subjects. The physiological TR has low velocities and right ventricular systolic pressure is in the normal range.

The physiological TR with the following criteria44:

- TR jet in RA < 1 cm long;

- TR jet area < 2.5 cm2;

- TR jet area / RA area < 18%.

**Tricuspid stenosis (TS)**

The echocardiography offers a etiologic, severity and functional diagnosis of this valvulopathy.The diagnosis uses M mode and two

dimensional (2D) data, which described the morphology and mobility of tricuspid valve. The continuous wave and color Doppler registered the diastolic tricuspid turbulent flow. The normal tricuspid inflow velocity is less than 0.5 to 1 m/s, with a mean gradient less than 2 mm Hg

The evaluation of TS severity uses methods similar to those employed for mitral stenosis:

- Continuous wave Doppler measurement of maximum and medium velocities and pressures on tricuspid inflow wave (Vmax, Vmean, Pmax, Pmean)

- Pressure half time (PHT) method with the constant of 190:

TV orifice area (S) = PHT/190

- The continuity equation.

The TS is considered severe when P mean ≥ 7 mm Hg, S ≤ 1 cm2, PHT > 190 ms.

The echocardiographic evaluation must include the measurements of the right atrium enlargement.

| | Tricuspid stenosis | Severity | |
|---|---|---|---|
| | Mild | moderate | severe |
| Mean gradient | <2mm Hg | 2-7 mm Hg | >7mm Hg |

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**Tricuspid regurgitation (TR)**

Doppler echocardiography represents the gold standard for diagnosis of TR. Continuous wave and color Doppler are the main methods of detection and quantification of severity of TR. Echocardiographic diagnosis uses M mode and 2D indirect data such as annulus dilation, enlargement of RV, raised RV/LV ratio, paradoxical IVS motion.

The underlying cause of TR can be detected by 2D and M-mode echocardiography. TR can be due to primary disease of TV or secondary to annulus dilation (functional TR).

| | Mild TR | Moderate TR | Severe TR |
|---|---|---|---|
| Valve morphology | normal | Normal/abnormal | abnormal |
| RA/RV/IVC size | normal | Normal/dilated | Dilated unless acute TR |
| CW jet | Less intense | Dense | Dense with late delay |
| Jet area | <5cm2 | 5-10cm2 | >10cm2 |
| Jet/RArea | <20% | 20-40% | >40% |
| Venacontracta | small | <7mm | >7mm |
| Hepatic vein flow | Systolicdominance | Systolic blunting | Systolic reversal |

18The severity of TR can range from mild to severe. It is important to remember that maximum velocity of tricuspid regurgitant flow represents the

pressure difference between RV and RA, and has nothing to do with TR severity grade. More than that, the intensity of continuous wave signal is directly proportional with TR severity and the shape of flow can suggest the acute TR (flow with early peak velocity and cut-off of descendent part of the slope).

Quantification of TR can be done in a manner analogous to that for the mitral valve but the publishing data are less well established. The intensity and the shape of continuous wave signal is useful to evaluate the TR severity of to differentiate an acute TR from a chronic one. When TR is severe, the dilation and systolic pulsation of inferior vena cava along with loss of respiratory variation in size can be detected. Additionally retrograde systolic flow in hepatic veins can be seen.

## SURGICAL DECISIONS

The cardiologist and the cardiac surgeon faces the decision of when to intervene and when to surgically repair or replace the tricuspid valve.7 The choice of the reparative technique to use for a durable result must be evaluated as well as evaluation of which type of valve, mechanical or bioprosthesis, to employ to maximize durability and minimize complications (i.e., thrombosis and thromboembolism). The surgical literature can be misleading due to case selection bias and the various time frames of retrospective reviews.

## ANNULOPLASTY TECHNIQUES

Techniques to deal with a dilated tricuspid valve annulus with normal leaflets and chordal structures include plication of the posterior leaflet's annulus (bicuspidization), partial purse-string reduction of the anterior and posterior leaflet annulus (DeVega technique), and rigid or flexible rings or bands placed to reduce the annular size and achieve leaflet coaptation. The preoperative and intraoperative echocardiograms are valuable assessment tools to help the surgeon understand the structure and function of the valve14.

The degree of pulmonary hypertension, right ventricular dilatation, and systolic function coupled with the size of the right atrium must be factored into the surgical decision making. The classical technique of inserting a finger via a purse-string suture into the right atrium to palpate the tricuspid valve and withdrawing the finger tip 2 to 3 cm from the valve orifice trying to access the force of the regurgitant jet is of less importance in the current era of cardiac surgery. Minimal right atrial enlargement and +1 to +2 regurgitation will usually resolve after surgery on left-sided valve lesions,especially if the pulmonary hypertension resolves. Otherwise, tricuspid annuloplasty should be performed to help improve the early postoperative course and prevent residual or progressive tricuspid regurgitation. Special note should be taken in assessing the foramen ovale for patency. These lesions should always

be sutured closed, reducing the possibility of arterial desaturation from right to left shunting or paradoxical embolization.

**Bicuspidization**

Suture plication to deal with mild dilation of the annulus is accomplished by placing pledgeted mattress sutures from the center of the posterior leaflet to the commissure between the septal and posterior leaflets. A second suture is often necessary to further reduce the annulus, ensuring proper leaflet coaptation while providing an adequate orifice for flow. An annuloplasty ring can be inserted to further support the annular reduction

**DeVega Technique**

The DeVega technique can also be employed for mild to moderate annular dilation. The technique employs a 2-0 Prolene or Dacron polyester suture placed at the junction of the annulus and right ventricular free wall, running from the anterior septal commissure to the posterior septal commissure. The second limb of the suture is placed through a pledget and run parallel and close to the first suture line in the same clockwise direction, placing it through a second pledget at the posterioseptal commissure. The suture is tightened, producing a purse-string effect and reducing the length of the anterior and posterior annulus to provide adequate leaflet coaptation and orifice of flow. The judgment regarding the degree of annular reduction has

varied from the guideline of being able to insert 2-1/2 to 3 finger breadths snugly through the valve orifice to using the ring annuloplasty sizers designed for the tricuspid valve. An annuloplasty sizer, chosen by measuring of the intertrigonal distance, can be used as a template while tying the purse-string suture to achieve the proper degree of reduction. The DeVega and suture plication techniques should be reserved for mild annular reductions and situations in which the structural integrity of the annulus is not absolutely necessary for long-term success (i.e., functional tricuspid regurgitation expected to resolve over time)13. In these situations the annuloplasty provides a competent tricuspid valve during the early postoperative course while the heart remodels after surgical treatment of the left-sided valvular lesions.

**Rings and Bands**

Significant degrees of annular reduction requiring durability are best accomplished with rigid rings (Carpentier-Edwards),flexible rings (i.e., Duran), or flexible bands (i.e., Cosgrove annuloplasty system). The length of the base of the septal leaflet (intertrigonal distance) determines the size of the ring or band. These devices avoid suture placement in the region of the AV node to avoid postoperative conduction problems. It allows the tricuspid valve orifice to be primarily occluded by the leaflet tissue of the anterior and septal leaflets. Overly aggressive annular reduction can lead to ring dehiscence due to excessive tension on the tenuous tricuspid valve tissue

**Intraoperative assessment of the repair**

Assessment of tricuspid valve competence after the annuloplasty requires filling the right ventricle with saline and observing the leaflet coaptation.. If the result appears inadequate, replacement should be performed. Final assessment is by TEE examination after completely weaning from cardiopulmonary bypass with appropriate volume and afterload adjustment12,13.

**Tricuspid valve replacement**

Tricuspid valve replacement with a homograft is complicated. The homograft tissue is a mitral valve. Sizing is performed by measuring the intratrigonal distances13. Fixation of the papillary muscles is either intracavity (right ventricle)or through the wall of the right ventricle.. An annuloplasty ring is inserted to prevent dilatation and ensure adequate leaflet coaptation. Special care is necessary in suture placement to avoid conduction disturbances.. Similar to mitral valve replacement, leaflet and chordal preservation should be performed to maintain annular papillary muscle continuity.

Carpentier techniques for mitral valve repair can be applied to the tricuspid valve. Traumatic disruptions, occasionally endocarditis with healed lesions and perforations, or the rare myxomatous valve can be repaired. Pericardial patching of perforations, partial leaflet resections of the anterior

(limited) or posterior (extensive) leaflets, and ring annuloplasty are standard techniques to produce competent valves and avoid replacement. In infective endocarditis Tricuspid valve excision is possible if pulmonary pressures are not elevated and the degree of infection is extensive. Blood flows passively through the right heart to the lungs. After eradication of the infection, a second-stage procedure with valve replacement can be performed months to years later when all infection is eradicated. 55 .Homograft tissue is often versatile for partial or total tricuspid valve repair or replacement.

**PROSTHETIC VALVE CHOICE**

The choice of prosthesis follows an algorithm similar to that used for valve replacement in other cardiac valve positions. The patient's age, anticoagulation considerations, whether the patient is a young woman during her childbearing years, and social issues must be considered. The previously reported poor results with mechanical valves in the tricuspid position were due to valve thrombosis. Most of these reports were during the era of cage-ball and tilting-disc prosthesis. More recent reports with the St. Jude bileaflet valve have provided encouraging data, allowing the surgeon to recommend a mechanical valve with confidence to younger patients who do not have a contraindication to anticoagulation. . Bioprostheses, both porcine and of pericardial tissue, have functioned well in the tricuspid position. The data demonstrate a longer

duration of freedom from structural valve dysfunction or re-replacement for a bioprosthetic valve in the tricuspid compared to the mitral valve position.

In the tricuspid position it is always possible to place large bioprosthetic or mechanical valves. Prostheses with more than a 27-mm internal diameter do not have clinically significant gradients. Therefore hemodynamic performance is rarely an issue for tricuspid valve replacement. The data demonstrate excellent results with modern bileaflet mechanical valves. Series comparing bioprosthetic and mechanical valves have been consistent in demonstrating equality during the period of follow-up.

Some patients with mitral valve disease undergoing surgery with tricuspid regurgitation do not require surgical treatment of the tricuspid valve. Guidelines to identify these patients are poorly developed35. Experience has shown that careful observation of the patient preoperatively is quite valuable. Absence of tricuspid valve regurgitation during periods of good medical control, absence of tricuspid regurgitation by transesophageal echo at the time of operation, minimal elevation of pulmonary vascular resistance, and absence of right atrial enlargement are helpful findings permitting the surgeon to confidently replace the mitral valve without performing an annuloplasty or replacement of the tricuspid valve.37,38

Clinical experience has demonstrated that up to 20% of patients undergoing mitral valve replacement receive a tricuspid

annuloplasty but less than 2% require replacement. The surgeon's clinical judgment and experience guide the approach to tricuspid valve surgery and ultimately lead to variability in reported clinical data. The accuracy of the judgments can be guided by assessment of the risk factors for persistent or progressive tricuspid valve regurgitation.26 They are related to unresolved or recurrent mitral valve pathology, the degree of preoperative tricuspid regurgitation or the misjudgment of its severity, failure of the pulmonary hypertension and pulmonary vascular resistance to resolve, resulting in persistent impairment in right ventricular function, and failure to recognize organic tricuspid valve disease.

The durability of simple annuloplasty techniques such as bicuspidization and the DeVega has been good when employed only for mild to moderate degrees of functional tricuspid regurgitation with successful resolution of pulmonary hypertension after the mitral valve operation. Extensive experience with the tricuspid annuloplasty using the Duran, Carpentier-Edwards, or Cosgrove rings or bands resulted in an 85% freedom from moderate to severe tricuspid regurgitation at 6 years. The subsequent requirement for tricuspid reoperation is very low. Inadequate resolution of the mitral disease and persistent pulmonary hypertension with right ventricular dilation and dysfunction are the major predictors of poor late results.

The display of cardiac anatomy in three dimensions from any perspective would have clear advantages over conventional 2D imaging and provide an insight into the functional and anatomic properties of cardiac structures. One of the main advantages of live 3D TTE is its “surgeon’s eye” view of the cardiac anatomy36. The technique is finding a niche in preoperative planning, particularly for tricuspid valve repair A volume rendered 3D image of the tricuspid valve can be reconstructed from any perspective. So, preoperative detection of tricuspid valve by 3D ECHO will be helpful for the surgeon in better planning

**THREE DIMENSIONAL ECHOCARDIOGRAM**

Three dimensional (3D) echocardiography offers the ability to improve and expand the diagnostic capabilities of cardiac ultrasound.

**BACKGROUND**

Attempts to record and display ultrasound images in 3D format were first reported in the 1960s. More than a decade later, investigators began to obtain 3D ultrasound images of the heart. Through the careful tracking of a transducer, a sequence of 2-dimensional (2D) echocardiograms could be recorded, aligned, and reconstructed into a 3D data set. This methodology was limited by the need for offline data processing to create and display the 3D images. In the early 1990s, von Ramm and colleagues developed the first real-time 3D (RT3D) echocardiographic scanner capable of acquiring volumetric data at frame rates sufficient to depict cardiac motion25.

# METHODOLOGY

**Transducer design**

Breakthrough in 3D technology is possible by piezoelectric crystals development. Conventional transducer- consist of 64 to 128 elements . These elements are arranged along a single row. 3D transducer has more than 3000 elements arranged in rows and columns.. These elements are electrically independent. 3D transducer has 150-boards. In these dense array real-time 3D transducer, each square represents an element and Entire crystal of the transducer head is sampled or covered with elements33. The micro beam former is required for this arrangement to provide a communication of all of the (3000) elements to the ultrasound system.

So, beem steering is very powerful.

**Reconstruction Techniques**

Early approaches to 3D echocardiography were based on the principle that a 3D data set could be reconstructed from a series of 2D images. In this method, serial 2D images are obtained using either freehand scanning or a mechanically driven transducer that sequentially recorded images at predefined intervals. More recently, the use of a transesophageal or transthoracic multiplane probe has emerged as a readily available method to obtain rotational images at defined interval angles around a fixed axis. Typically, images are

collected over a 180-degree rotation at set intervals. To minimize reconstruction artifacts, sequential images are gated to both electrocardiography and respiration. Acquisition of a complete data set typically takes 1 to 5 minutes, depending on respiratory and heart rates and the predefined spatial intervals.The quality of 3D reconstructions from 2D images depends on a number of factors, including the intrinsic quality of the ultrasound images, the number of the 2D images used to reconstruct the 3D image, the ability to limit motion artifact, and adequate ECG and respiratory gating. Once the 2D images have been obtained, they are processed offline with customized or commercially available software. The cardiac structures are manually or semiautomatically traced to the 3D spatial coordinates to reconstruct a 3D image

**Real-Time 3D Acquisition Methods**

The development of RT3D echocardiographic systems circumvents many of the disadvantages of reconstructive methods. RT3D echocardiography uses a transducer with ultrasound elements arranged in a grid fashion transmitting at a frequency of 2.5 or 3.5 MHz. Current RT3D systems use matrix-array transducer technology with a greater number of imaging elements, typically containing more than 3000 imaging elements, compared with the 256 in the sparse-array transducer. These current matrix-array transducers offer

improved resolution and are rapidly becoming the primary technique for 3D data acquisition in clinical and research practice.

In addition, these matrix-array transducers display either online 3D volume-rendered images or 2 to 3 simultaneous orthogonal 2D imaging planes. To minimize reconstruction artifacts, data should be acquired during suspended respiration if possible.39

3D spatial modes consists of

1-live 3D mode –instantaneous 2- live 3D mode zoom-instantaneous

3-full voume –gated. 4-3D colour doppler- gated.

**Live 3D mode/zoom –instantaneous**

The system scans in real time 3 dimensions.If the transducer comes off the chest –the image disappears.The volume pyramid may be reduced to zoom in three dimensions- Live 3D zoom-instantaneus RT3D is the only on-line 3D method based on real time volumetric scanning, as compared with other 3D imaging techniques- MRI, CT.

**Full voume –gated**

Gating allows a technique to generate wider volumes while maintaining frame rate.

Gating is done by stitching 4 (or more) gates together in full-

volume mode. This can generate > 90 degree scanning volumes at frame rates >30 Hz.

Once a 3D data set is acquired, it must be sliced or "cropped" to visualize the cardiac structures within the pyramid Multiple cropping methods are available, but a common method displays 2 or 3 imaging planes simultaneously. Each of these imaging planes can be manipulated separately to appropriately align the cardiac structures. Another cropping method involves a single-slice plane that can be manually adjusted to expose and display the cardiac structures of interest

**Technical Factors**

The technical aspects of acquiring a high-quality, diagnostic 3D echocardiogram are similar to those for 2D echocardiography **.** Where as in 2D display which has rows and blocks of pixels( picture elements) in 3D data set it consists of bricks and pixels called volume elements or voxels. 3D Data set (collection of voxels) can be rotated with respect to the computer screen. . The use of optimal gain settings before acquisition is essential for accurate diagnosis.. Most 3D echocardiographic systems use some form of gating to obtain volumetric data. Gated data sets are most challenging in patients with arrhythmias or respiratory difficulties. The confounding effects of the gating artifacts can be minimized in different ways.

**Protocols**

A complete 3D echocardiographic study includes an assessment of ventricular function, valvular morphology, and hemodynamic status. Unlike 2D echocardiography, in which standard views are described based on the plane through which they pass, 3D echocardiography is inherently volumetric. As such, it permits both an external view of the heart and multiple internal perspectives (through cropping). A general approach is to describe cardiac structures using both the ultrasound plane and the viewing perspective. Three orthogonal planes are recommended: (1) the sagittal plane, which corresponds to a vertical, long axis view of the heart; (2) the coronal plane, which corresponds to a 4-chamber view; and (3) the transverse plane, which corresponds to a short-axis view. Each plane can be viewed from 2 sides, which represent opposite perspectives; for example, the transverse plane, which represents the short-axis view, can be visualized from the perspective of the apex or base; the coronal plane can be viewed from above or below; and the sagittal plane can be viewed from the left or right. The choice of narrow-angle or wide-angle imaging acquisition modes depends on the cardiac structure to be examined. For imaging of the ventricles, it is best to use a wide-angle acquisition in the apical window. Instead of a complete 3D echocardiogram, a more focused 3D imaging study may be appropriate in some cases. For example, in a patient with tricuspid stenosis, the 3D portion of the study may be limited to visualization and quantification of the tricuspid orifice. The ability

to extract hemodynamic information derived from 3D color Doppler ultrasonography is currently being investigated. To capture and analyze color flow imaging in 3 dimensions, the area of interest should be obtained within the 3D data set, with the angle of the ultrasound beam aligned as parallel as possible to the direction of blood flow. The color Doppler flow patterns can be analyzed in multiple views to provide a complete assessment of the color Doppler data

The benefits of 3DE are particularly well suited to the study of the tricuspid valve . The assessment of patients with functional tricuspid regurgitation and tricuspid stenosis is one of the most promising clinical applications of this technology. For reconstruction of the tricuspid valve in adult patients, transthoracic echocardiography is the routine approach for 2D image acquisition. Images from transthoracic echocardiography are interfaced with a 3D computer system which incorporates the steering logic for acquisition of a rotational dataset and software for 3D reconstruction and display. From the resultant dataset, novel 2D cut planes in any orientation can be selected (any plane echo) and multiple parallel cross sectional 2D slices can be generated in any desired plane (para plane echo).

However, as with any emerging technology, the enthusiasm to embrace a new technique must be tempered by a critical appraisal of the evidence supporting its use. It is essential to assess the limitations as well as the unique

capabilities it provides. To justify the use of a new 3D modality, its unique contribution to clinical practice must be critically analyzed.

In a study done by “Renate schnabel,.second johannes gutenberg-university, germany, (echocardiography, volume 22, january 2005)” 57 to demonstrate the feasibility of transthoracic three-dimensional real-time echocardiography (3D TTE) supplemental to routine assessments of the tricuspid valve and to analyze inter rater agreement she concludes that 3D

TTE of the tricuspid valve can be performed in addition to routine 2D echocardiography within a reasonable time and with high assessability of important features in patients with right ventricular failure. Thus, its feasibility may encourage prospective studies on its potential for more detailed noninvasive diagnosis and preoperative planning. In a study by "koteswara Pothineni, et al university of alabama at birmingham in echocardiography, volume 24, may 2007, "live/real time three-dimensional transthoracic echocardiographic assessment of tricuspid valve pathology: incremental value over the two-dimensional technique*"42 ,*states that our preliminary experience with 3D TTE has demonstrated substantial incremental value over 2D TTE in the assessment of various tricuspid pathologies. In addition, color doppler 3D TTE provided an estimate of quantitative evaluation of TR severity, since the exact shape and size of the vena contracta could be accurately assessed

In a study by "Thanh-Thao Ton-Nu, MD Geometric Determinants of Functional Tricuspid Regurgitation Insights From 3-Dimensional Echocardiography **[**Circulation. 2006;]"58 states that Little is known about the normal 3D shape of the TV and annulus and changes that occur with functional TR. Their study was to examine the 3D geometry of the TV annulus (TVA) under normal circumstances and in patients with functional TR, relating the geometric changes in the tricuspid annulus between normal controls and functional TR. They concluded that the normal Tricuspid Annulus by 3D echo is a bimodal non planar structure. With development of functional TR,the annulus becomes larger, more planar, and circular. The changes in annular geometry that occur with functional TR can be visualized by 3D Echo and can have potentially important mechanistic and therapeutic implications for repair.

# MATERIAL AND METHODS

This study was performed in the Department of Cardiology, Government General Hospital, Chennai, during the year 2006– 2009.

## STUDY INDICATION

Study indication was for the comprehensive assessment of qualitative and quantitative analysis of tricuspid valve in both normal and diseased states and its correlation with 3D echocardiography and 2D echocardiography

## STUDY GROUP SELECTION

Seventy patients and ten controls attending government general hospital were selected for the study. Patients suspected of tricuspid valve disease both organic and functional were carefully evaluated by history taking, physical examination and laboratory tests, including electrocardiography chest radiographs, and echocardiography. Color Doppler 2D echo was done in all cases They were divided into three groups

### Group 1

Patients with anatomical normal tricuspid leaflets with right ventricular pressure or volume over load. It includes

1. Rheumatic heart disease with mitral heart disease with pulmonary hypertension

2. Primary pulmonary hypertension

3. Pulmonary hypertension secondary to chronic pulmonary thromboembolism

4. Atrial septal defects

Group 2

Patients with anatomical abnormal valve

It includes

1. Rheumatic tricuspid stenosis with tricuspid regurgitation

2. Ebsteins anomaly of tricuspid valve

3. Infective endocarditis of tricuspid valve

Group 3 –Controls

All controls had sinus rhythm and normal right-sided heart (normal right ventricular dimensions and function, normal right atrial dimension, trivial or absent tricuspid regurgitation and normal tricuspid valve function

All participants were informed about the purpose of the study and consent was obtained

Exclusion criteria: The following group of patients were excluded from the study

1. patients with inadequate window

2. patients with skeletal abnormalities

3. Patient with chronic obstructive pulmonary disease

4. patients with post myocardial infarction left ventricular dysfunction

5. Dilated cardiomyopathy with left ventricular dysfunction.

**CLNICAL EVALUATION**

The study group consisted of 70 patients and 10 controls of 30 males and 50 females. Detailed clinical examination was done in all cases. ECG, X-ray chest, 2D echocardiogram were done in all cases on admission Patients were analysed whether they had history of rheumatic fever and whether they were in sinus rythm. Patients underwent 2D echocardiogram and all cases were analyzed by 3D echocardiogram.

**ECHOCARDIOGRAPHY STUDY**

All patients in the study underwent 2D Echocardiographic evaluation at the time of admission with a Philips iE 33 ultrasound machine The Tricuspid valve was imaged from parasternal long axis , parasternal short axis ,Right ventricular inflow and apical four chamber views with the patient in the left lateral decubitus position .RV end-diastolic dimension was obtained in

the parasternal view at the base per American Society of Echocardiography guidelines.

In each patient, following points were checked for visualization:

1) tricuspid annulus, 2) TV leaflets (ATL PTL and STL) 3) TV commissures

(antero-septal, antero-posterior, and postero-septal) All these structures were classified according to a subjective 4-point scale for image quality

1 = not visualized,

2 = inadequate,

3 = sufficient

4 = good.

The following variables were measured

(1) Tricuspid annular diameter diastolic [TAD,] obtained from the apical 4-chamber (AP4CH) and parasternal short axis (PSAX) views at an end-diastolic TAD

(2) TAD systolic obtained from the apical 4-chamber (AP4CH) and parasternal short axis (PSAX) views at an end-systolic still frame,

(3)

(4) Tricuspid annular fraction shortening (TAFS) defined as (end-diastolic TAD-end-systolic TAD)/end-diastolic TAD obtained from the AP4CH and PSAX.

(4) TV leaflets (number, mobility, thickness and relation to each other),

(5) TV area

(6) TV commissures (antero-septal, antero-posterior, and postero- septal)

(7) TR degree was assessed by vena contracta (VC) width and ratio of maximal TR jet area to the corresponding right atrial area averaged from parasternal and apical views. pulmonary hypertension was defined as an RVSP of >30 mm Hg

(8) Right ventricular systolic pressure (RVSP) was estimated from the tricuspid re gurgitant velocity with the modified Bernoulli equation with 10 mm Hg for right atrial pressure.

(9) LV ejection fraction (LVEF) was calculated by biplane Simpson's method.

(10) RV dilation was defined by a RV minor-axis diameter of 35mm at the base in the apical 4-chamber view.

## REAL TIME THREE DIMENSIONAL ECHOCARDIOGRAPHY

In each patient, RT3DE is performed immediately after 2D study using a Philips iE 33 ultrasound machine with an X3-1 probe. RT3DE examination is performed from the same windows that are used for 2D echocardiography, namely parasternal long axis, parasternal short axis, apical, and inflow views. Hence the plane of examination and the views are exactly similar to that of 2D echocardiography. The 3D data set, including that for the entire TV, was acquired in 7 consecutive cardiac cycles with ECG gating full volume 3D data set was collected within approximately 5–10 s of breath holding in full volume mode from an apical window. Gain and compression controls as well as the time gain compensation settings were optimized for the quality of the 3D images. The 3D data set was transferred for off-line Data analysis of 3D images was based on a 2D approach relying on images obtained initially from the apical view. The 3D geometry of the tricuspid valve was analyzed with software for visualization and analysis of 3D echocardiographic data

The Tricuspid valve was sliced between two narrow lines to exclude other tissues on the 2D image leading to clarification of annulus by a 3D image. This image was viewed and traced from the atrial and ventricular aspect, In each patient, following points were checked for visualization:

1) tricuspid annulus,
2) TV leaflets ( anterior posterior and septal)
3) TV commissures (antero-septal, antero-posterior, and postero- septal)

All these structures were classified accordingto a subjective 4-point scale for image quailty

1 = not visualized,

2 = inadequate,

3 = sufficient

4 = good

. The following RT3DE variables were obtained from both an end-diastolic and end-systolic still frame:

(1) Major TV annulus diameter and minor TV annulus diameter defined as the

widest diameter that could be measured from an end-diastolic still frame and end systolic frames.

2) maximal TV annulus area obtained from an end-diastolic still frame and measured by manual planimetry

3) TV area defined as the narrowest part of the TV at the time of maximal opening and measured by manual planimetry

4) TV leaflets (number, mobility, thickness and relation to each other),

5) TV commissures(antero-septal, antero-posterior, and postero- septal) including the position of their closure lines.

6) TV commissural width obtained from a late diastolic still frame using zoom function to avoid underestimation. The images were optimized for each commissure along its plane to measure the

maximal width of the angle formed by the two adjacent TV leaflets.

In patients with rheumatic heart disease with relevant tricuspid valve involvement. 2DE data obtained were: (1) tricuspid valve leaflet separation (TV-$LS_{2D}$) defined as the distance between the tricuspid valve tips at the maximal opening obtained from an apical four-chamber) and parasternal short-axis window (2) tricuspid annular diameter ($TAD_{2D}$) obtained from an apical four-chamber and parasternal short-axis view at an end-Diastolic and end systolic still-frame; (3) descriptive morphology of the tricuspid valve leaflets including thickness, mobility and calcification and the mean pressure gradient across the tricuspid valve RT3DE data obtained were: (1) $TAD_{3D}$ defined as the widest TAD that could be measured from an end-diastolic and end systolic still frame; (2) maximal tricuspid annulus area ($TAA_{3D}$) obtained from an end-diastolic still frame and measured by manual planimetry; (3) tricus pid valve area ($TVA_{3D}$) defined as the narrowest part of the tricuspid valve at the time of maximal tricuspid valve opening and measured by manual planimetry; (4) descriptive tri cuspid valve morphology scored for each tricuspid valve leaflet; and (5) commissural width for each tricuspid valve commissure (anteroseptal, anteroposterior and posteroseptal), obtained from an end-diastolic still frame

In Ebsteins anomaly the extent of displacement of the septal and posterior leaflets,severity of TR ,extent of tethering and the presence of bubbles in 3D were noted and in infective endocarditis the invovment of each leaflet and the severity of tricuspid regurgitation were noted .

# RESULTS

The study group consisted of eighty subjects,functional tricuspid valve Group consists of 40 patients [10 males and 30(75%) females]. Organic tricuspid valve disease group consist of 30 subjects that includes 22 females and 8 males and the control group had 5 males and 5 females. Age ranges from 20 to 40 years. Mean age was 24.9 .Group 1 included patients with anatomical normal tricuspid leaflets with right ventricular pressure_or volume over load.This included patients with RHD mitral valve disease[5 Males and 25 females ],primary pulmonary hypertension [0 Males and 3 females ],pulmonary thromboembolism[1Males and 0females ]and atrial septal defects [2Males and 2 females ] . Group 2_includes patients with anatomical abnormal tricuspid valve It includes patients with Rheumatic tricuspid stenosis with tricuspid regurgitation [8 Males and16 females ], Ebsteins anomaly of tricuspid valve[0Males and 4 females ], and Infective endocarditis of tricuspid valve[0 Males and 2 females ]. Group 3 includes Controls [5 males and 5 females]

## GROUP I

### GROUP II

**Table 1**

| | males | females |
|---|---|---|
| functional tricuspid | 10 | 30 |
| Organic tricuspid | 8 | 22 |
| Controls | 5 | 5 |

**Table 2**

| | Male | female |
|---|---|---|
| RHD mitral valve disease | 5 | 25 |
| Primary pulmonary hypertension | 0 | 3 |
| PTE | 1 | 0 |
| ASD | 2 | 2 |

**Table 3**

| | males | females |
|---|---|---|
| Rheumatic tricuspid stenosis with tricuspid regurgitation | 8 | 16 |
| Ebsteins anomaly of tricuspid valve | 0 | 4 |
| Infective endocarditis of tricuspid valve | 0 | 2 |

In standard two dimensional echo tricuspid valve cross-sections (apical 4-chamber, parasternal short-axis and parasternal long-axis right ventricular inflow) were visualised. In the apical 4-chamber view in all patients and the controls the septal leaflet was seen adjacent to the septum and the anterior leaflet was seen adjacent to the right ventricular free wall. In the parasternal short-axis view, the posterior leaflet was seen adjacent to the right ventricular free wall in 92% of patients and the leaflet adjacent to the aorta the anterior leaflet was visualised in 42% of the controls In group I in the parasternal short-axis view the posterior leaflet was visualized in 95% and the anterior in 57%and in 90% and 40% in group II patients In the parasternal right ventricular inflow view the leaflets seen were identical to the apical 4-chamber view with in all patients the septal leaflet seen adjacent to the septum and the anterior leaflet seen adjacent to the right ventricular free wall in controls and patients .All three leaflets could not be visualized simultaneously in 2D echo

Acquisition and analysis of the RT3DE data was performed in approximately 10 min per patient. The Tricuspid valve could be visualized in 90% of patients enface from both ventricular and atrial aspects in relation to adjacent cardiac structures. Detailed analysis of the tricuspid valve was performed including tricuspid annulus shape and size, Tricuspid leaflets shape, size, and mobility, and commissural width.

**Tricuspid annulus**

Tricuspid annulus visualization was good in 6 patients (60%), sufficient in 3 patients (30%), and inadequate in 1 patients (10%).in controls . Tricuspid annulus shape appeared as oval rather than circular.

Tricuspid annulus diameter and area could be measured in 7 patients (70%), normal values were 4.0 8± 0.18cm and 10.4± 5.7 cm2, respectively. In group 1 patients detailed analysis of the Tricuspid annulus was performed. Tricuspid annulus visualization was good in 24 patients (60%), sufficient in 16 patients (40%) . Tricuspid annulus shape appeared as oval rather than circular. Tricuspid annulus diameter and area could be measured in 36 patients (90%), values were 5.05 ± 0.43cm and 20.77± 4.3cm2, respectively

**Tricuspid valve leaflets**

Visualization of the three tricuspid leaflets (in motion) was good in 8 controls (80%), sufficient in 1control (10%), and inadequate in another 1 control (10%). Visualization of the triangular shaped Tricuspid valve area was good in 5 controls (55%), sufficient in 3controls (30%), and inadequate in 2 controls The anterior leaflet was the largest and most mobile of the three leaflets and had a nearly semicircular shape. The septal leaflet was the least mobile and had a semi-oval shape. Its position was parallel to the interventricular septum. The posterior leaflet was the smallest one with variable shape. It was clearly separated from the septal leaflet in all patients but

in 10% of patients it was hard to discriminate the posterior leaflet from the anterior leaflet even during maximal tricuspid valve opening . In group 1 patients Visualization of the three tricuspid leaflets (in motion) was good in 32 patients (80%), sufficient in 4 patients (10%), and inadequate in another 4 patients (10%). Visualization of the triangular shaped tricuspid valve area was good in 22 patients (55%), sufficient in 13 patients (30%), and inadequate in 5 patients(15%).

**Tricuspid valve commissures**

The commissures and the direction of closure lines were good visualized in 5 controls (50%), sufficient in 2control s (20%), inadequate in 2 controls (20%), and not visualized in 1control (10%). Tricuspid commissural width could be obtained in 6 control s (60%), mean commissural width in these patients was 3.4 ± 1.5 mm for the anteroseptal commissure, 3.2 ± 1.5 mm for the posteroseptal commissure, and 3.1 ± 1.1 mm for the antero-posterior commissure, respectively. In group I patients Visualization and measurement of commissures was relatively easy for the antero-septal commissure and most difficult for the antero-posterior commissure. The commissures and the direction of closure lines were good visualized in 20 patients (50%), sufficient in 8 patients (20%), inadequate in 8 patients (20%), and not visualized in 4 patients (10%). TV commissural width could be obtained in 30 patients (80%), mean commissural width in these patients was 3.0 ± 1.5 mm for the anteroseptal commissure, 3.4 ± 1.5 mm for the posteroseptal commissure, and 3.0 ± 1.1 mm for the antero-posterior commissure, respectively .All echocardiographic parameters and visualization comparison scores of Tricuspid structures were significantly higher in group I patients (all *P*<0.001) when compared to controls Patients were classified into group I with RV minor-axis diameter of 35mm at the base in the apical 4-chamber view

**Scores for real-time three-dimensional echocardiography in controls**

| | annulus TV | visualization of TV structures leaflets | TV commissures | TV area |
|---|---|---|---|---|
| Good | 60% | 80% | 50% | 50% |
| Sufficient | 30% | 10% | 20% | 30% |

| | | | | |
|---|---|---|---|---|
| Inadequate | 1o% | 10% | 20% | 20% |
| not visualized | 0 | 0 | 10% | 0 |

**Scores for real-time three-dimensional echocardiography in group I**

| | annulus TV | visualization of TV structures leaflets | TV commissures | TV area |
|---|---|---|---|---|
| Good | 60% | 80% | 50% | 55% |
| Sufficient | 40% | 10% | 20% | 30% |
| Inadequate | 0 | 10% | 20% | 15% |
| not visualized | 0 | 0 | 10% | 0 |

**Comparison between 2D and 3D measurements**.

The Tricuspid annulus was clearly delineated in all patients and, its shape was not circular but oval, both in normal sized and in dilated tricuspid annulus . Tricuspid annulus diameter defined as the widest diameter that could be measured from an end-diastolic still frame was compared between group 1 and controls.

There was a good correlation between end-diastolic tricuspid annular diameter $_{2D\text{-}AP4CH}$ and tricuspid annular diameter $_{2D\text{-}PSAX}$. Major tricuspid annular diameter $_{3D}$ was greater than the end-diastolic tricuspid annular diameter $_{2D\text{-}AP4CH}$ and tricuspid annular diameter $_{2D\text{-}PSAX}$ ($P$<0. 001). Major tricuspid annular diameter $_{3D}$ measurements in both the controls and the patient groups were significantly larger than end-diastolic tricuspid annular diameter$_{2D\text{-}AP4CH}$ and tricuspid annular diameter $_{2D\text{-}PSAX}$. Also when the largest tricuspid annular diameter $_{2D}$ was compared to tricuspid annular diameter$_{3D}$, 3D measurements were significantly larger (5.05±0.43cm and 3.96±0.45 cm, $P$<0.005).

There was an excellent correlation between end-systolic tricuspid annular diameter $_{2D\text{-}AP4CH}$ and tricuspid annular diameter$_{2D\text{-}PSAX}$ .Major systolic tricuspid annular diameter$_{3D}$ measurements were significantly larger than end-systolic tricuspid annular diameter$_{2D\text{-}AP4CH}$ and tricuspid annular diameter$_{2D\text{-}PSAX}$ (R=0.80, $P$<0.0001 and R=0.66, $P$<0.005, respectively). Major systolic tricuspid annular diameter$_{3D}$ measurements were in both patient groups significantly greater than end-systolic tricuspid annular diameter$_{2D\text{-}AP4CH}$ and tricuspid annular diameter$_{2D\text{-}PSAX}$. There were no significant differences between tricuspid annular fraction shortening $_{2D\text{-}AP4CH}$ (1.4±0.14%), tricuspid annular fraction shortening $_{2D\text{-}PSAX}$ (1.33±0.28%), and tricuspid annular fraction shortening $_{3D}$ (1.8±0.1%). $TAFAC_{3D}$ was significantly higher (2.38±0.08%; *P*<0.0001).

**Tricuspid valve area**

Visualization of the triangular shaped tricuspid valve area was good in 5 controls (55%), sufficient in 3 controls (35%), and inadequate in 2controls (15%), The anterior and septal leaflets formed the tricuspid valve area's angle and the small posterior leaflet formed its base. Tricuspid valve area could be measured in 8 controls(%) and mean tricuspid area in these patients was 4.93 ± 1.6 cm2. In group I patients Visualization of the triangular shaped tricuspid valve area was good in 24 patients (55%), sufficient in 10 patients (30%), and inadequate in 6 patients(15%).

| | Controls (*n*=10) | Group I (*n*=40) |
|---|---|---|
| Clinical characteristics | | |
| Age (years) | 24.5±1.2 | 25.2±2.4 |
| Male gender (%) | 5(50%) | 10 (25%) |
| Diastolic echo values | | |
| $TAD_{2D\text{-}AP4CH}$ (cm) | 3.19±0.34 | 3.96±0.45 |
| $TAD_{2D\text{-}PSAX}$ (cm) | 3.17±0.32 | 3.29±0.23 |
| Major $TAD_{3D}$ (cm) | 4.08±0.18 | 5.05±0.43 |
| Minor $TAD_{3D}$ (cm) | 3.11±0.35 | 4.21±0.52 |
| $TAA_{3D}$ ($cm^2$) | 10.4±5.7 | 20.77±4.3 |
| Systolic echo values | | |
| $TAD_{2D\text{-}AP4CH}$ (cm) | 2.59±0.34 | 3.88±0.54 |
| $TAD_{2D\text{-}PSAX}$ (cm) | 2.56±0.22 | 3.37±0.38 |
| Major $TAD_{3D}$ (cm) | 2.6±0.19 | 4.17±0.7 |
| Minor $TAD_{3D}$ (cm) | 2.51±0.25 | 3.49±8.1 |
| $TAA_{3D}$ ($cm^2$) | 8.14±2.8 | 15.04±2.9 |
| Fractional shortening | | |
| $TAFS_{2D\text{-}AP4CH}$ | 1.4±0.14 | 1.51±0.14 |
| $TAFS_{2D\text{-}PSAX}$ | 1.33±0.28 | 1.51±0.12 |
| $TAFS_{3D\ MAJOR\ TAD}$ | 1.8±0.1 | 1.61 ±0.13 |
| $TAFAC_{3D}$ | 2.38±0.08 | 2.72±0.21 |
| Tricuspid regurgitation | | |
| None | 7 (70%) | 0 (0%) |
| Grade 1–2 | 3 (30%) | 10 (50%) |
| Grade 3–4 | 0 (0%) | 10 (50%) |

In patients with rheumatic heart disease with relevant tricuspid valve involvement tricuspid annular diameter 3D was larger than tricuspid annular

diameter 2D in all patients without tricuspid valve stenosis, regardless of the 2DE view used (mean values were 4.47cm for TAD3D, 36 cm for TAD2D-AP4CH and 35 cm for TAD2D-PSAX).

Mean (SD) Tricuspid valve area 3D [ TVA3D] in the patients with tricupid valve stenosis was 2.04 cm2 . TVA3D was significantly related to the transtricuspid mean pressure gradient.(5.11 mm of hg) (r =20.76). RT3DE and morphological description (including thickness, mobility, calcification and position) were possible for each separate tricuspid valve leaflet. The grade of tricuspid valve leaflet affection scored with 2DE and RT3DE were similar in terms of thickness, mobility and calcification. However, RT3DE could also assess individual tricuspid valve leaflet position (relative to other tricuspid valve leaflets) and the extent of tricuspid valve affection. In addition, all three commissures could be adequately evaluated with RT3DE, including assessment of commissural width during maximal tricuspid valve opening. Tricuspid valve commissural width could be obtained in 30 patients (80%), mean commissural width in these patients was 1.5 ± 1.0mm for the anteroseptal commissure, 1.04 ± 1.5 mm for the posteroseptal commissure, and 1.1 ± 1.1 mm for the antero-posterior commissure, respectively, patients with tricuspid valve stenosis had significantly smaller commissural width

**Fractional shortening**

**Rheumatic tricuspid stenosis 2Dand 3D Echo parameters**

| | RHD TS -3D<br>N=22 | RHD TS 2D<br>N=22 |
|---|---|---|
| All leaflets visualised | 90% | two leaflets in a view |
| Commisures | 75% | Nil |
| Tricuspid annulus diameter | 4.47 _+0.42cm | 3.6_+0.37cm |
| Thickness of leaflets | 3.9+_o.8mm | 3.7+_0.7mm |
| Tricuspid valve area | Planimetry | By pht |
| | 2.04+_0.9cm sq | 1.9+_1cm sq |
| | | Mean gradient =5.11mm of hg |

**3D echo in controls and organic tricuspid stenosis**

| | RHD TS -3D<br>N=22 | Controls<br>N=10 |
|---|---|---|
| Tricuspid valve area by planimetry | 2.04+_0.9cm sq | 4.93+_2.6cmsq |
| Tricuspid annular area by planimetry | 12.08±2.3cm2 | 8.14±2.5 cmsq |
| Commisural distance | 1.04 ± 1.5 mm | 5.4 ± 1.5 mm |

The 2D and 3D findings of patients with Ebsteins anomaly studied are given in the table .For the purpose of analysis each separate leaflets were analysed the extent of displacment of each leaflet and the presence of bubbles were noted in 3D echo. 3D echo visualizes the posterior leaflet involved in tethering and the extent of displacement was noted which was not possible with 2D. The mean displacement of the septal leaflet was 17mm and that of posterior leaflet was 16 mm . 3D echo also reveals the extent of the tethering in each leaflets which is not possible with 2D echo. 3DTTE reveals that the severity of TR is moderate if both the leaflets are involved and the extent of tethering is more

**2D and 3D findings of patients with Ebsteins**

ATL

STL

PTL by 3D

TR severity

Case 1

no tethering

tethering present basal segment

displacement 15 mm

tethering present basal segment

displacement 13 mm

mild

Case 2

no tethering

tethering present in basal and apical segments

displacement 18mm

tethering present basal segment

displacement 18mm

Moderate

Case3

no tethering

tethering present basal and apical segments

displacement 17mm

tethering present basal and apical segment

displacement 15 mm

Moderate

Case4

no tethering

tethering present basal and apical segments

displacement 14mm

tethering present basal segment

displacement 15 mm

mild

**T Test**

The t test procedure is used to compares mean scores for the 2D and 3D Echo methods. The procedure assumes that the variances of the two groups are equal and it was tested with Levene's test statistics. The results of the analysis are given in Table

TAD [redacted]

The table displays the descriptive statistics of the sample size, mean, standard deviation for tricuspid annular diameter in group I by 2D and 3D echo The P value shows the probability value from the t distribution. Since the P value is less than 0.01 it is significant at 1%.

**2D and 3D four chamber view of RHD mitral stenosis with TR**

**Measurements of tricuspid annulus diameter and valve thickness by 2D**

**Assessment  of TR by color and continuous Doppler in 2D**

**3 D image Acquisition with volume gating**

**3D image cropping of tricuspid valve**

**Cross section of tricuspid and mitral annulus by 3D echo**

**Measurements of the commisures and annulus area and diameter**

**3D echo image of Tricupid valve**

**Measurement of Tricuspid annulus diameter and area by3D**

**Assessment of Tricuspid valve area by 3D and gradient across TV Doppler by 2D**

**Rheumatic mitral valve disease with functional TR 3D image**

**3D echo showing the tricuspid commisures  and leaflets**

**Organic Rheumatic tricuspid stenosis by 3D**

**3D apearance  of infective endocarditis of tricuspid valve**

**3D appearance  of vegetation  of tricuspid valve by 3D**

**2D four chamber view of ebteins anomaly and TR by color**

**3D echo showing all leaflets and extent of displacement in ebsteins**

**3D echo showing TR and extent of tetheringof septal leaflet**

**3D echo showing the displacement of  the posterior leaflet**

# DISCUSSION

**TWO-DIMENSIONAL ECHOCARDIOGRAPHY IS A VALUABLE IMAGING MODALITY FOR THE FUNCTIONAL ASSESSMENT OF TRICUSPID VALVE . HOWEVER, WITH 2D ECHO IT IS NOT POSSIBLE TO VISUALIZE ALL TRICUSPID CUSPS SIMULTANEOUSLY IN ONE CROSS-SECTIONAL VIEW NOR CAN DETAILED ANATOMICAL INFORMATION OF THE TRICUSPID ANNULUS, LEAFLETS, AND COMMISSURES BE PROVIDED. PREVIOUS STUDIES AND CASE REPORTS DESCRIBED VISUALIZATION OF RICUSPID VALVE BY RT3DECHO IN ABNORMAL STATES, WHILE THIS STUDY APPLIED RT3D ECHO FOR THE MORPHOLOGICAL ASSESSMENT OF THE NORMAL TRICUSPID ANATOMY IN NORMAL AND ABNORMAL STATES. RT3DE ALLOWED ANALYSIS OF TRICUSPID ANNULUS, LEAFLETS AND COMMISSURES IN THE CONTROLS AND MAJORITY OF PATIENTS IN BOTH GROUP I AND GROUP II PATIENTS. VISUALIZATION OF THE SPATIAL RELATIONSHIP BETWEEN THE TRICUSPID VALVE AND VICINAL STRUCTURES, OF THE COMMISSURES, THE ORIFICE, AND ENTIRETY OF VALVE DEPICTION WERE BETTER IN THE GROUP I AS COMPARED TO THE CONTROL GROUP. ALL ECHOCARDIOGRAPHIC PARAMETERS AND VISUALIZATION OF TRICUSPID STRUCTURES WERE SIGNIFICANTLY HIGHER IN GROUP I PATIENTS (ALL *P*<0. 001) WHEN COMPARED TO CONTROLS VISUALIZATION OF COMMISSURES AND MEASUREMENT OF ITS WIDTH WERE OBTAINED WITH DIFFICULTY, IN PARTICULAR FOR THE ANTERO-POSTERIOR COMMISSURE.. FOR PROPER ASSESSMENT OF THE THREE COMMISSURES, MORE CUT PLANES WITH DIFFERENT ANGLES ARE NEEDED . BESIDE THIS MORPHOLOGIC DESCRIPTION, QUANTITATIVE ASSESSMENT COULD BE OBTAINED .IN A STUDY IN INT JOURNAL OF CARDIOVASCULAR IMAGING (2007) "ASSESSMENT OF NORMAL TRICUSPID VALVE ANATOMY IN ADULTS BY REAL-TIME THREE-DIMENSIONAL ECHOCARDIOGRAPHY" BY ASHRAF M. ANWAR ET AL 41 REPORTS THAT IT WAS POSSIBLE TO ANALYSE TRICUSPID VALVE ANATOMY BY RT3DECHO AND A DETAILED ANATOMICAL STRUCTURE INCLUDING UNIQUE DESCRIPTION AND MEASUREMENT OF TRICUSPID ANNULUS SHAPE AND SIZE, TRICUSPID LEAFLETS SHAPE, AND MOBILITY, AND TRICUSPID COMMISSURAL WIDTH WERE OBTAINED IN MAJORITY OF PATIENTS. ANNULAR DIMENSIONS WERE EQUALLY ASSESSABLE IN BOTH GROUPS, LEAFLET THICKNESS AND MOBILITY WERE NOT SIGNIFICANTLY DIFFERENT.**

The 3D-TTE exam including offline evaluation took 6.5 minutes on average and maximally 14 minutes however, it should be noticed that only patients with good 2DE image quality underwent RT3DE. In a study was done by Renate schnabel,.second johannes gutenberg-university, germany, (echocardiography, volume 22, january 2005*)20* to demonstrate the feasibility of transthoracic three-dimensional real-time echocardiography supplemental to routine assessments of the tricuspid valve commissures, the orifice, and entirety of valve depiction were better in the ventricular failure group as compared to the control group. In our study also the visualisation and the measurements were better in group I when compared to controls .Annular dimensions were equally assessable in both groups, leaflet thickness and mobility were not significantly different. Nevertheless, RT3DE allowed tricuspid valve analysis to a level quite comparable to that recently reported by others for the mitral valve leaflets . One of the salient findings in our study was the identification of the tricuspid leaflets in the routine 3DE views.

Tricuspid annular diameter measurements are of critical importance in the Tricuspid valve surgical decision-making process. Absence of TR or the presence of only mild TR does not mean that the tricuspid valve is free of any abnormality such as tricuspid annular dilatation. At a given time, even considerable tricuspid annular dilatation may not always result in significant TR. The changes in the tricuspid annulus with functional TR, namely, increased annular area, planarity, and circularity, have also been observed in the mitral annulus with functional mitral regurgitation. As the annulus becomes more circular with TR, there is greater enlargement of the anteroposterior distance than the mediolateral distance, which may result from dilation of the tricuspid annulus preferentially along its free-wall distance, Functional TR is increasingly recognized as a significant cause of morbidity and mortality, and accordingly, there has been a greater impetus to perform tricuspid valve repair at the time of surgery for left-sided disease.. Dreyfus 48et al demonstrated that the decision to perform tricuspid annuloplasty based on tricuspid annular dilation rather than degree of TR at the time of surgery resulted in improved long-term outcome. Matsunaga and Duran50 have demonstrated preoperative tricuspid annular dilation to be associated with development of late postoperative TR after repair of ischemic mitral regurgitation.Unfortunately, the success of tricuspid valve repair is often uncertain .Not only the selection of patients undergoing surgery for TR is dependent on echocardiographic Tricuspid annular diameter assessment, but also the type of surgical technique (valve plication or ring placement) is influenced by measurements of tricuspid annular function and tricuspid annular diameter.

Studies have demonstrated that healthy subjects had a non planar shaped tricuspid annulus with homogeneous contraction49. In patients with functional TR, the annulus was dilated in the septal to lateral and posteroseptal to anterolateral directions, thereby resulting in a more circular tricuspid annular shape. Contraction of the tricuspid annular was then asymmetrically decreased. More interestingly, the nonplanar and non–single-plane structure of the tricuspid annular was observed both in healthy subjects and in patients with TR.in 3D echo A similar geometric pattern was observed between them, but the more severe the TR, the more planar the tricuspid annulus.

Although 2D TTE is helpful to assess tricuspid valve function and to detect TR severity it has important limitations in describing tricuspid valve morphological details, such as tricuspid annular diameter. RT3DE may yield more detailed anatomical information In the present study, the morphological and functional aspects of the TA were assessed by RT3DE. In our study tricuspid annulus diameter and area could be reliably obtained with RT3DE .The main findings of our study are (1) tricuspid annular shape was not circular but oval, both in normal sized and in dilated, tricuspid annulus (2) tricuspid annular diameter is underestimated by 2D TTE. In the present study, we can show that changes in the 3D annular shape predicted functional TR, by annular area. .In a study by Thanh-Thao Ton-Nu, MD Geometric Determinants of Functional Tricuspid RegurgitationInsights From 3-Dimensional Echocardiography [Circulation. 2006;58] concluded normal 3D shape of the

tricuspid valve and annulus and changes with functional TR and becomes larger, more planar, and circular

**A MAJOR CONTRIBUTION OF 3DTTE OVER 2DTTE WAS THE EN FACE VISUALIZATION OF ALL THREE LEAFLETS OF THE TRICUSPID VALVE IN ALL PATIENTS. THE PRESENT STUDY OFFERS MECHANISTIC INSIGHTS THAT CAN POTENTIALLY BE APPLIED TO IMPROVE REPAIR FOR FUNCTIONAL TR IN BOTH OPERATIVE AND NEWLY EMERGING PERCUTANEOUS APPROACHES. AND HENCE, ACHIEVEMENT OF A NON PLANAR SHAPE MAY BE AN IMPORTANT THERAPEUTIC GOAL BEYOND THAT OF ANNULAR REDUCTION ALONE .THE PRESENT STUDY FINDINGS ALSO CONFIRM THOSE OF HIRO ET AL, WHO EXAMINED TRICUSPID ANNULAR SHAPE IN SHEEP USING SONOMICROMETRY AND ALSO DEMONSTRATED A NONPLANAR GEOMETRY ASSESSMENT OF THE TRICUSPID VALVE MORPHOLOGY BY TRANSTHORACIC REAL-TIME-3D-ECHOCARDIOGRAPHY.**

In the present study, the Tricuspid annulus was visualized well in all subjects allowing even measurements of its area, both at end-systole and end-diastole. This is in accordance with a 3D study by Schnabel et al. in which tricuspid annular visualization was good or at least sufficient in over 90% of patients. When tricuspid annular diameter $_{2D}$ measurements were compared with the tricuspid annular diameter $_{3D}$ measurements, 2D measurements were significantly smaller than the major tricuspid annular diameter $_{3D}$ measurements. In fact, tricuspid annular diameter $_{2D}$ measurements corresponded more with the minor tricuspid annular diameter $_{3D}$ measurements. In 2D TTE studies it was shown that the normal value for tricuspid annular

diameter is <35 mm. However, in our study half of the patients with a normal tricuspid annular diameter $_{2D}$ had an actual tricuspid annular diameter (measured with 3D) larger than 35 mm. So, 2D TTE cannot be relied on defining tricuspid annular diameter as normal. It seems necessary to re-establish normal tricuspid annular diameter values with 3D imaging.

Like other cardiac structures, cyclic changes occur in tricuspid annular diameter during systole and diastole. Calculation of TAFS from systolic and diastolic tricuspid annular diameter showed no stastical difference between 2D TTE and RT3DE. This is because end-systolic and end-diastolic tricuspid annular diameter $_{3D}$ values are to an equal extent increased compared with 2D values.

Calculation of tricuspid annular function by $TAFAC_{3D}$ was significantly higher than that measured by diameter changes either in 2D TTE. This could be explained by the accuracy of global function by area percent changes than single distance percent changes especially when more lengthening occurs. All our RT3DE measurements were consistent with the measurements described in anatomical studies.

Visualization of the triangular shaped tricuspid valve area was good and mean tricuspid valve area in these controls were 4.93 ± 2.6 cm2. With RT3DE, each separate tricuspid valve leaflet can be assessed with regard to thickness, mobility, calcification and its relationship to other tricuspid valve

leaflets. The grade of tricuspid valve leaflet affection scored with 2DE and RT3DE were similar in terms of thickness in our study . In addition, RT3DE provides unique tricuspid valve measurements such as Tricuspid valve area $_{3D}$ and commissural width at the time of maximal tricuspid valve opening. Mean Tricuspid valve area $_{3D}$ in the patients with tricupid valve stenosis was 2.04 $cm^2$

This distance between the tricuspid valve commissures during diastole was found to be narrowed in rheumatic tricuspid stenosis and may be a new indicator of tricuspid valve stenosis severity. In our study, Tricuspid valve area $_{3D}$ had better discriminative value than mean gradient for the separation of patients with rheumatic heart disease with tricuspid valve involvement from those with rheumatic heart disease without tricuspid valve involvement In addition, Tricuspid valve area could be reliably obtained and this may have important implications for the diagnosis of tricuspid stenosis. However, assessment of commissural width may also be a valuable tool for the diagnosis, follow up, and selection of therapeutic strategy of tricuspid stenosis.

In patients with Ebsteins 2D echo and 3D echo values were compared . 3D echo visualizes the posterior leaflet involved in tethering and the extent of displacement was noted which was not possible with 2D . 3D echo also reveals the extent of the tethering in each leaflets which is not possible with 2D echo The ability to acess the full extent and distribution of tethering of tricuspid leaflets has important implications when considering patients for tricuspid valve repair or replacement by the surgeons .The more the extent of tethering and more the leaflets involved the degree of TR was severe.

RT3DE allowed accurate assessment of Tricuspid valve orifice area in patients with infective endocarditis.53 Loss of Tricuspid leaflet tissue, defects in Tricuspid leaflets and size of TV systolic non-coaptation could also be delineated and resulted in identifying the mechanism of tricuspid regurgitation (TR) in patients with infective endocarditis. 3DTTE also permitted sectioning of various tricuspid valve vegetations for more specific diagnosis of their nature52.

In addition, color Doppler 3D TTE provided an estimate of quantitative evaluation of TR severity, since the exact shape and size of the vena contracta could be accurately assessedIn a study by Koteswara Pothineni, et al frrom university of Alabama at Birmingham in echocardiography, volume 24, may 2007, " live/real time three-dimensional transthoracic echocardiographic assessment of tricuspid valve pathology: incremental value over the two-dimensional technique"43 ,states that their preliminary experience with 3DTTE has demonstrated substantial incremental value over 2DTTE in the assessment of various TV pathologies. Our data may potentially take RT3DE a step further into clinical routine providing accurate Tricuspid valve measurements and may enhance the understanding of Tricuspid valve morphology during the cardiac cycle. Also, the detailed assessment by RT3DE may affect the therapeutic decision of various TV abnormalities and thus expand the abilities of non-invasive cardiology

## LIMITATIONS OF THREE DIMENSIONAL ECHOCARDIOGRAPHY

The standard of the 3D reconstructed display depends critically on the quality of the original 2D cross sectional images.During data acquisition three-dimensional echocardiographic reconstructions are also very sensitive to both patient and operator movement, either of which can distort the image and result in dropout which may be misinterpreted. There are several possible limitations of three-dimensional volume-rendered echocardiographic reconstructions. This technique is extremely sensitive to proper gain settings from the two-dimensional data acquisition as well as to the level of threshold chosen (which defines the interface between tissue and blood) during the three-dimensional reconstruction.

Atrial fibrillation or a variable respiratory pattern prolongs the acquisition time and impairs the data set resulting in artifact.Therefore; measurements on reconstructed images should be made with caution. The study need to be compared with magnetic resonance imaging(MRI) which is the gold standard for tricuspid valve disorders

## 3D FUTURE DIRECTIONS

Ongoing developments in 3D echocardiography include technological innovations and expanding clinical applications. Automated surface extraction and quantification, single-heartbeat full-volume acquisition, transesophageal

RT3D imaging, the ability to navigate within the 3D volume, and stereoscopic visualization of 3D images are some of the technological advances that can be expected over the next several years. These will further enhance the quality and clinical applications of 3D echocardiography.

In addition, standardized and focused 3D protocols will be developed and refined to optimize clinical application of this technique. Tagging and or tracking the LV surface in real time may provide new approaches to quantifying myocardial mechanics, such as regional shape and strain. This approach has great potential and will complement and likely compare favorably with the quantitative ability of cardiac MRI. The superior temporal resolution of echocardiography should offer unique advantages for this purpose .In the future, combining the greater temporal resolution of 3D echocardiography with the excellent spatial resolution of MRI may yield an imaging data set with unsurpassed anatomic and physiological information, an approach called “fusion imaging.

# CONCLUSIONS

1. Real time three dimensional echocardiography of the tricuspid valve can be performed in addition to routine two dimensional echocardiography within a reasonable time and with high assessability

2. The Tricuspid annulus in three dimensional echocardiography is an oval structure with a major and a minor diameter

3. Two dimensional Transthoraxic echo underestimates tricuspid annular diameter when compared to three dimensional echo , regardless whether it is measured from the apical 4-chamber or parasternal short axis view This may have important implications in the tricuspid valve surgical decision-making processes.

4. Real time three dimensional echocardiography provides unique tricuspid valve measurements such as Tricuspid valve area which can be used to access the severity of tricuspid stenosis

5. Commissural width at the time of maximal tricuspid valve opening can be measured. This distance between the tricuspid valve commissures during diastole may be a new indicator of tricuspid valve stenosis severity

6. Real time three dimensional echocardiography provides an comprehensive assessment of Ebstein anomaly,the extent of displacement of posterior leaflet and the extent of tethering and would be an valuable supplement to 2D echo

7. By combining all information obtained by 2D and RT3DE, the diagnostic and therapeutic decision-making process regarding the tricuspid valve may be facilitated

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## GLOSSARY AND ACRONYMS

| | | |
|---|---|---|
| TEE | - | Trans esophageal echocardiogram. |
| 2DTTE | - | Trans thoracic echocardiogram. |
| RT3D E | - | Real Time 3 Dimentional Echocardiogram. |
| MRI | - | Magnetic Resonance Imaging. |
| RV | - | Right ventricle; LV-Left ventricle. |
| TAD | – | tricuspid annular diameter |
| TVA | – | Tricuspid valve area |
| TV | – | Tricuspid valve |
| TAA | - | Tricuspid annular area |